Nanoparticle Emissions of a small Piston- Engine powered Aircraft

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It is shown, that not only combustion of diesel or kerosene can form nanoparticles! An AVGAS (Aviation Gasoline) powered piston engine for small aircrafts, was tested at different power settings.
The tested aircraft is a Robin DR-400-500, registered under HB-KEZ for the Federal Office for Civil Aviation in Bern, Switzerland. The engine is a Lycoming IO-360-A1B6 piston engine. Tests were done together with DLR-Stuttgart at the airport of DLR- Oberpfaffenhofen.
It is recommended from the engine manufacturer to run the engine under rich conditions in order to keep engine temperatures low. The fuel rich conditions give extremely high CO values. Under these conditions it is not surprising, that soot particles are formed. As an indicator for "cold and rich flames" we measured carbonyl compounds in the exhaust gases, too.
The tests are ground level tests at different power settings. The probe was connected direct into the exhaust. Sampling line was a 4,5m long stainless steel tube with 6mm inner diameter, heated to 150 °C. The sample was diluted by a factor of 10, using a DEKATI dilution system. Aerosol measurements are done with a TSI SMPS system with long DMA.
Samples are taken at the power settings TAXI, APPROACH, CRUISE and CLIMB.

	Mean diameter (nm)	total conc. (# / cm^3)
TAXI	49	5.7 E7
APPROCH	104	1.0 E8
CRUISE	89	6.9 E7
CRUISE (lean)	77	9.1 E7
Climb	62	6.7 E7

Cruise was tested under rich and lean conditions. The lean test point show smaller particle diameter, but higher number concentration.
AVGAS 100 LL is a leaded fuel with 56 mg Pb /litre. It is to check if the particles are only black carbon, or there are PbO particles too? Further tests are planed with leaded and unleaded fuel.

Deutsches Zentrum für Luft- und Raumfahrt e.V.

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Robin DR 400 / 500
HB-KEZ Federal Office for Civil Aviation
Bern, Switzerland

Test Conditions: Ground level tests

Engine: Lycoming(TM) IO-360-A1B6

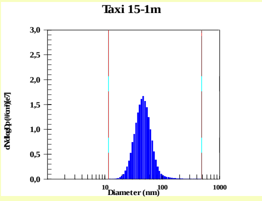
Fuel: AVGAS 100 LL

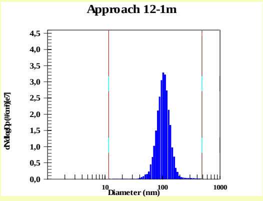
Sampling Line: 4,5 m stainless steel at 150°C

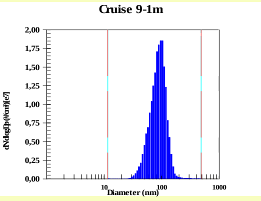
Diluter: Dekati 1:10

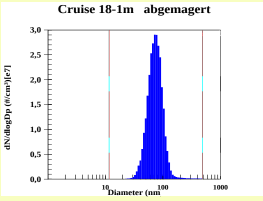
TSI SMPS System

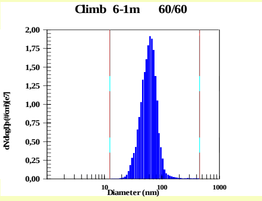
Sampling Probe











SMPS - Results after multiple charge correction:

	mean d (nm)	total conc. (# /cm³)	mass Density 1,2 (µg/m³)
TAXI	**49**	**5,7 E7**	**8,9 E3**
APPROACH	**108**	**8,6 E7**	**9,4 E4**
CRUISE	**91**	**6,1 E7**	**4,3 E4**
CRUISE lean	**78**	**8,2 E7**	**3,8 E4**
CLIMB	**63**	**6,2 E7**	**1,7 E4**

Carbonyl Measurements

	Climb		Approach		TAXI		Blind
	ppb	mg/kg Fuel	ppb	mg/kg Fuel	ppb	mg/kg Fuel	ppb
Formaldehyd	8337,48	92,49	6346,26	68,98	5867,59	68,24	21,29
Acetaldehyd	999,68	16,27	744,04	11,87	848,79	14,48	7,08
Propanal	639,90	13,73	532,20	11,19	707,13	15,91	0
Aceton	98,92	2,12	95,11	2,00	95,59	2,15	10,26
1-Buten-3-on	831,43	21,53	781,08	19,82	862,45	23,41	0
Methacrolein	213,53	5,53	184,10	4,67	198,74	5,40	0
Butanal	87,75	2,34	0	0	0	0	0
Benzaldehyd	347,12	13,61	297,51	11,43	333,92	13,72	0
o-Toluolaldehyd	162,52	7,21	141,79	6,17	136,54	6,35	0
m-Toluolaldehyd	294,13	13,06	260,23	11,32	281,54	13,10	0
p-Toluolaldehyd	79,40	3,52	80,54	3,50	71,96	3,75	0
Summe	12091,88	191,42	9462,85	150,95	9404,27	166,51	38,63

Conclusion:

Aviation Gasoline powered piston engines for small aircraft can form nanoparticles in the same size range and number concentration like diesel cars or JET-A1 powered gas turbines!

Cruise was tested under rich and lean conditions. The lean test point show smaller particle diameter, but higher number concentration.
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